The need and requirement for analyzing electrical hazards in the workplace has never been greater. The electrical industry overall has become increasingly aware of the needs and requirements, largely due to the increased emphasis by OSHA, NFPA 70E, NESC, and other consensus standards, along with a better understanding of the gravity of electrical hazards. In past decades, industry, for the most part, chose to react to catastrophic accidents and incidents rather than to predict and/or prevent them. This has now turned around, and the vast majority are now performing an electrical hazard analysis, developing electrical safety programs and procedures, and providing the required personal protective equipment and electrical safety training for their employees.

A discussion of the electrical hazards and the analysis required will provide an even better understanding of why these analyses must be performed.

Electrical hazard analysis

Electrical hazards in all industry sectors consist of electrical shock, electrical arc flash, and electrical arc blast. The magnitudes of these hazards, the required electrical safety programs and procedures, and the necessary personal protective equipment (PPE) are all determined by performing the electrical hazard analysis. This analysis or assessment is required by several regulations and standards. A brief description is provided here for a better understanding of the requirements.

The OSHA Act of December 29, 1970, provides the following:

“An Act – To assure safe and healthful working conditions for working men and women…”

Section 5. Duties
“(a) Each employer:
(1) shall furnish to each of his employees employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm to his employees;
(2) shall comply with occupational safety and health standards promulgated under this Act.
(b) Each employee shall comply with occupational safety and health standards and all rules, regulations, and orders issued pursuant to this Act which are applicable to his own actions and conduct.”

All electrical hazards are recognized hazards; therefore, the electrical hazard analysis must be performed.

OSHA 29 CFR 1910.132(d) states:
“The employer shall assess the workplace to determine if hazards are present, or are likely to be present, which necessitate the use of personal protective equipment (PPE).”

OSHA 29 CFR 1910.335, Safeguards for Personnel Protection provides additional considerations as follows:

“1910.335 Safeguards for personnel protection.
(a) Use of protective equipment.
(1) Personal protective equipment.
(i) Employees working in areas where there are potential electrical hazards shall be provided with, and shall use, electrical protective equipment that is appropriate for the specific parts of the body to be protected and for the work to be performed.”
(a) Employees shall wear protective equipment for the eyes or face wherever there is danger of injury to the eyes or face from electric arcs or flashes or from flying objects resulting from electrical explosion.

(2) General protective equipment and tools.
   (i) When working near exposed energized conductors or circuit parts, each employee shall use insulated tools or handling equipment if the tools or handling equipment might make contact with such conductors or parts.
   (ii) Protective shields, protective barriers, or insulating materials shall be used to protect each employee from shock, burns, or other electrically related injuries while that employee is working near exposed energized parts which might be accidentally contacted or where dangerous electric heating or arcing might occur.

NFPA 70E-2009, Standard for Electrical Safety in the Workplace, Section 110.8(B)(1) provides the requirements for the (a) Shock-Hazard Analysis and (b) Arc-Flash Hazard Analysis. Section 130.2 provides the information required to perform the Shock-Hazard Analysis and Section 130.3 provides the information required to perform the Arc-Flash Hazard Analysis.

The National Electrical Safety Code (NESC) C2-2007, 410 General Requirements provides direction to assess the workplace to determine potential exposure to an electric arc.

On June 15, 2005, OSHA issued a Proposed Rule to revise 29 CFR 1910.269 and 1926, Subpart V to include the requirement to assess the workplace to determine potential exposure to an electric arc.

Shock-hazard analysis

Hundreds of workers are killed every year as a result of inadvertent contact with energized conductors. Investigations into the causes of these fatalities point to three principal factors:

• Failure to properly or completely de-energize systems prior to maintenance or repair work
• Intentionally working on energized equipment
• Improper or inadequate grounding of electrical system components

These three factors form the basis for analysis for the electrical shock hazard.

To appropriately assess the electrical shock hazard associated with any type of maintenance or repair work, it is necessary to evaluate the procedures or work practices involved. These, in turn, should be evaluated against regulatory and standards requirements.

Regulatory requirements

- All equipment must be de-energized prior to any maintenance or repair work (limited exceptions exist).
- The de-energized state must be verified prior to any work and maintained through the consistent use of locks and tags and, in some cases, grounding.
- When required, energized work must be performed in accordance with written procedures.

NFPA 70E-2009 standard requirements

- The Shock-Hazard Analysis must establish the:
  1. Limited Approach Boundary
  2. Restricted Approach Boundary
  3. Prohibited Approach Boundary
- This applies to all exposed live parts operating at 50 volts or more
- Only qualified persons are permitted beyond the restricted approach boundary. Unqualified persons must be continuously escorted by a qualified person to enter the limited approach space.
- Unqualified person may not enter these boundaries unless the conductors and equipment have been placed in an electrically safe work condition

In addition to assessing work practices, a shock hazard analysis must include an assessment of the physical condition of the installed electrical equipment and system. Although the continuity and low resistance of the equipment grounding system is a major concern for reducing the risk of electrical shock, it is not the only one. Of equal importance is ensuring that:

- Covers and guards are in place.
- Access to exposed conductors is limited to qualified persons only.
- Overcurrent protective devices are operable, of appropriate interrupting rating, and maintained in a safe and reliable condition.

Even the best procedures, when performed on poorly constructed or maintained equipment, represent a risk.

Arc-flash hazard analysis

An estimated 80 percent of all serious electrical injuries are related to electrical arcs created during short circuits and switching procedures. As a result of this, standards organizations have provided better techniques for evaluating both the magnitude of the arc-flash hazard and appropriate PPE and clothing.

The principle factors used to determine the arc-flash hazard are as follows:

1. Available short-circuit current at the arc location
2. Duration of the electrical arc
3. Distance from the arc to personnel
4. The arc gap

To accurately assess the arc flash hazard and make appropriate decisions regarding PPE, it is first necessary to understand the operation of the system under fault conditions. The analysis requires the available short-circuit current and the protective device clearing time. It is a common misconception that arc-flash hazards are a product of only high voltage. In truth, the actual arc-flash hazard is based on available energy, not available voltage.

With this information, the magnitude of the arc-flash hazard at each work location can be assessed using several techniques, including:

- **NFPA 70E, Standard for Electrical Safety in the Workplace**
- **IEEE 1584, IEEE Guide for Performing Arc-Flash Hazard Calculations**

The results of the arc-flash hazard analysis are most useful when expressed in the incident energy received by exposed personnel. Incident energy is commonly expressed in terms of calories per centimeter squared (cal/cm²). Arc-flash protective equipment and clothing are rated in terms of their arc thermal performance value (ATPV), also expressed in cal/cm².

In addition to arc-flash protective equipment and clothing, certain work practices can be adopted to minimize or eliminate the hazards, such as body positioning and insulated tools. Line clearance procedures and other factors must be carefully scrutinized to ensure the risk to employees is minimized.

As with the electrical shock hazard, the easiest and most effective way to mitigate the arc-flash hazard is to completely de-energize the equipment and/or system prior to any maintenance activity. NFPA 70E refers to this as placing it in an electrically safe work condition.

**Blast-hazard analysis**

An electrical blast or explosion is the result of the heating effects of electrical current and the ensuing arc. In an electrical arc, the super heated copper bus bars and cables vaporize, expanding at a factor of 67,000 times from the solid to the vapor state. This rapid expansion contributes to the arc blast. Little can be done to mitigate the blast hazard (at least in terms of PPE), but with sufficient manufacturer’s data, blast pressure calculations can be used to determine whether enclosures will withstand an internal fault. It may be more important to merely recognize the magnitude of the hazard so that appropriate safety practices, such as correct body positioning, can be incorporated into work procedures. When the blast hazard is high or located in a confined space, a blast can severely injure or kill a person. When such conditions exist, serious consideration should be given to not allowing personnel in the area during specific equipment operations.

**Selection of electrical PPE**

Most employers, operators, and electricians are knowledgeable in the selection and inspection requirements for electrical PPE used for the prevention of electrical shock hazards, as well as head, eye, hand and foot protective equipment. Unfortunately, many people have limited knowledge or experience in the arc and blast hazards that may be associated with the maintenance and operation of energized electrical equipment, not to mention the necessary PPE.

The Occupational Safety and Health Administration (OSHA) discusses PPE requirements in 1910 Subpart I. It states that the employer must “Select, and have each employee use, the type of PPE that will protect the affected employee from the hazards identified in the hazard assessment.”

Although OSHA does not identify specific clothing that should be worn to protect employees from arc-flash hazards, it does prohibit certain types. For example, OSHA 1910.269 states, “The employer shall ensure that each employee who is exposed to the hazards of flames or electric arcs does not wear clothing that, when exposed to flames or electric arcs, could increase the extent of injury that would be sustained by the employee.” This would include clothing made of acetate, nylon, polyester, or rayon.

OSHA requires protection from the hazards of electricity in 1910.335(a)(2)(ii) where contact might be made and where arcing might occur. The consensus standard for determining the necessary clothing and training is NFPA 70E-2009, Standard for Electrical Safety in the Workplace.

**Summary**

In analyzing electrical hazards in any industry, we must follow a path that will lead to a comprehensive analysis of the problems that exist and provide a quantified value to ensure the selection of appropriate PPE and clothing. An analysis of all three hazards must be completed followed by an action taken to prevent injuries.

The following steps can help ensure the adequacy of an electrical safety program and training for qualified electrical personnel:

- Conduct a comprehensive job/task analysis
- Complete a task hazard assessment, including:
  a. Shock hazard
  b. Arc-flash hazard
  c. Blast hazard
- Analyze each task hazard to determine the required PPE
- Conduct training needs assessment for qualified and nonqualified electrical workers
- Revise, update, or publish a complete “Electrical Safe Work Practices Program”
Regulatory agencies and standards organizations have long recognized the need to analyze the hazards of electrical work and plan accordingly for their mitigation. Unfortunately, many in the electrical industry continue to take their chances because nothing bad has happened to them—yet. As more information becomes available on the economic and human costs of electrical accidents, it is hoped that more industry stakeholders will recognize the need for both a systematic hazards analysis and an electrical safe work program emphasizing hazard identification and abatement.

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